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Solar Refrigeration Using Peltier Effect

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Abstract

In the recent years, we have many problem such as energy crises and environment degradation due to the increasing CO_2 emission and ozone layer depletion has become the primarily concern to both developed and developing countries. Our project utilizes the solar energy for its operation. Solar refrigeration using thermo-electric module is going to be one of the most cost effective, clean and environment friendly system. This project does not need any kind of refrigerant and mechanical device like compressor, prime mover, etc for its operation. The main purpose of this project is to provide refrigeration to the remote areas where power supply is not possible.

Keywords**:** Seebeck effect**,** Refrigeration, Peltier effect, Thermo-electric module, Solar energy.

1. Introduction

From last century till now refrigeration has been one of the most important factors of our daily life. The current tendency of the world is to look at renewable energy resources as a source of energy. This is done for the following two reasons; firstly, the lower quality of life due to air pollution; and, secondly, due to the pressure of the ever increasing world population puts on our natural energy resources. From these two facts comes the realization that the natural energy resources available will not last indefinitely.
The basic idea is implementation of photovoltaic driven refrigerating system powered from direct current source or solar panel (when needed) with a battery bank. In 1821, the first important discovery relating to thermoelectricity occurred by German scientist Thomas Seebeck who found that an electric current would flow continuously in a closed circuit made up of two dissimilar metals, provided that the junctions of the metals were maintained at two different temperatures. Without actually comprehending the scientific basis for the discovery, Seebeck, falsely assumed that flowing heat produced the same effect as flowing electric current. Later, in 1834, while investigating the Seebeck Effect, a French watchmaker and part-time physicist, Jean Peltier found that there was an opposite phenomenon where by thermal energy could be absorbed at one dissimilar metal junction and discharged at the other junction when an electric current flows within the closed circuit. Afterwards, William Thomson described a relationship between Seebeck and Peltier Effect without any practical application. After studying some of the earlier thermoelectric work, Russian scientists in 1930s, inspired the development of practical thermoelectric modules based on modern semiconductor technology by replacing dissimilar metals with doped semiconductor material used in early experiments.
The Seebeck, Peltier and Thomson effects, together with several other phenomena, form the basis of functional thermoelectric modules. Thermoelectric Refrigeration aims at providing cooling effect by using thermoelectric effects rather than the more prevalent conventional methods like those using the ‘vapour compression cycle’ or the ‘gas compression cycle’.

2. Definition

The Seebeck coefficient is the ratio between the elecric field and the temperature gradient. The Seebeck coefficient can be thought of as a measure of the coupling between the thermal and elecrical currents in a material.

The Peltier coefficient of the junction is a property depending on both materials and is the ratio of the power evolved at the junction to the current flowing through it.

The Thomson coefficient is the ratio of the Power evolved per unit volume in the sample to the applied current and temperature gradient.

3. Construction

The construction setup of the refrigerator is as follows,

1. Thermo-electric module
2. Refrigeration chamber
3. Battery
4. Solar cell
5. Frame

3.1 Thermo-electric module

A thermo-electric module (TEM) is a solid state current device, which, if power is applied, move heat from the cold side to the hot side, acting as a heat exchanger. This direction of heat travel will be reversed if the current is reversed. It is a phenomenon that is opposite to the Seebeck effect. Combination of many pairs of p- and n-semiconductors allows creating cooling units - Peltier modules of relatively high power. A Peltier module consists of semiconductors mounted successively, which form p-n- and n-p-junctions. Each junction has a thermal contact with radiators. When switching on the current of the definite polarity, there forms a temperature difference between the radiators one of them warms up and works as a heatsink, and the other work as a refrigerator.
A TE module is composed of two ceramic substrates that give foundation and also electrical insulation to p-type and n-type semiconductors. The TE module is composed of silicon bismuth semiconductor cause this pair gives the highest COP.
Specification,

1. Material used- Silicon - Bismuth
2. A = 0.04 x 0.04 = 0.0016 m2
3. Q max =33.3 watt
4. V max = 14.8 v dc
5. I max =6 amp

3.2 Refrigeration chamber

The chamber used is same as that of the chambers used in conventional refrigeration. The chamber can be of any volume, shape and size. For experimentation purposes the volume of the chambers is kept low. Insulation provided to the chamber is done by polystyrene. And aluminium casing is done in the inner side of insulation to provide better cooling. We have used specific chamber and is as follows,

1. The size of the box is,
   - Width - 28.7 cm,
   - Length - 31.8 cm,
   - Height - 33.7 cm.
2. The power capacity is 60 W
3. The capacity of cooling chamber is 7.8 L.

4. The voltage is 240 V to 220 V AC and 12 V DC.

3.3 Battery

The battery is an electrochemical converting chemical energy into electrical energy. The main purpose of the battery is to provide a supply of current for operating the cranking motor and other electrical units. Specification,

1. Voltage 12v
2. Current 7.2Ah

3.4 Solar cell

The direct conversion of solar energy is carried out into electrical energy by conversion of light or other electromagnetic radiation into electricity.

1. The dimensions of the panel are-
   - Length – 48.5 cm,
   - Width – 35 cm.
2. Number of sub-cells used is 72
3. Dimension of the sub-cells is,
   - Length – 4.8 cm
   - Width – 4 cm.
4. Maximum power is 20 W
5. Voltage is 17 V
6. Current is 1.16 A

3.5 Frame

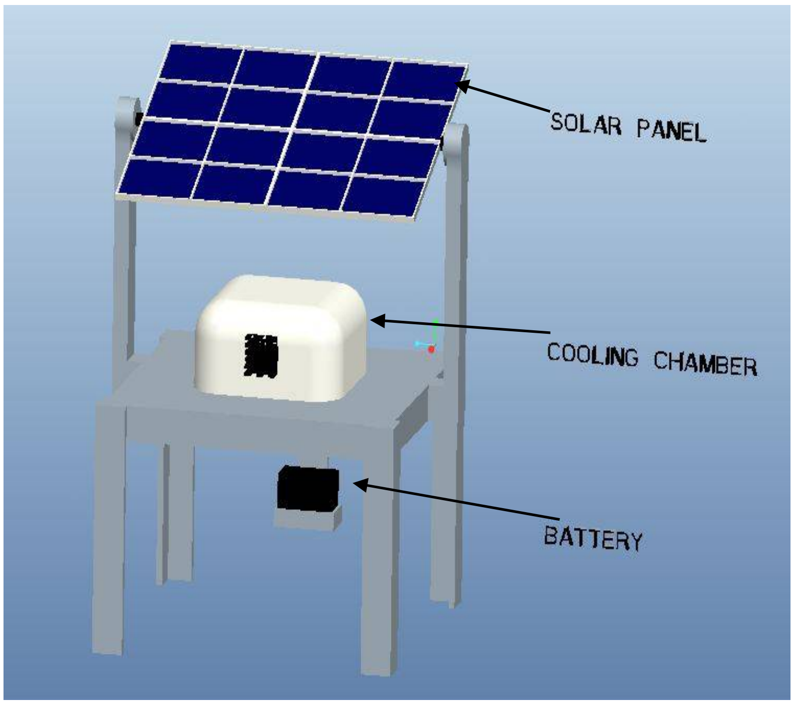
4. Working of Thermo-electric module

It is an equipment, which work on principle of conversion of solar energy into electrical energy. A solar cell is used to develop 17 V & 1.16 amps current DC supply and 20W. This electrical energy is stored in a battery which is of 12volts DC supply which then supplies the power to transformers.The transformer control three fan out of which two-fan work as exhaust fan & remove heat from heat sink plate. The third in side fan work as heat extractor, this fan remove heat from system and add to heat sink.During operation, DC current flows through the TEM causing heat to be transferred from one side of the TEC to the other, creating a cold and hot side.The p-type semiconductor is doped with certain atoms that have lesser electron than necessary to complete the atomic bonds within the crystal lattice. When electrons do this, they “holes” which essentially are atoms within the crystal lattice that now have local positive charges. Electrons are then continually dropping in and being bumped out of the holes and moving on the next available hole. In effect, it is the hole that are acting as the electrical carrier now electron move much more easily proper conductor but not so easily in semiconductor. When electron leave the p-type and enter into the copper on the cold side, hole are created in the p-type as the electron jump out to the higher energy level to match the energy level of the electron already moving in the copper. The extra energy to create this hole comes by absorbing heat. Meanwhile, the newly created hole travels downwards to the copper on the hot side. Electrons from the hot side copper move into the p-type and drop into the hole, releasing the excess energy in the form of heat the n-type semiconductor is doped with atoms that provide more electrons than necessary to complete. The atomic bonds within the crystal lattice. When a voltage is applied, this extra electrons are easily moved into the conduction band. However additional energy is required to get the n-type electrons to match the energy level of the incoming electrons from the cold side copper. The extra energy comes by absorbing heat. Finally, when the electrons leave the hot side of the n-type, they once again can move freely in the copper. They drop down to a lower energylevel, and release heat in the process.The COP for heating and cooling are thus different, because the heat reservoir of interest isdifferent. When one is interested in how well a machine cools, the COP is the ratio of the heat removed from the cold reservoir to input work. However, for heating, the COP is the ratio of the heat removed from the cold reservoir plus the input work to the input work:

4.1 Working design

This project's aim is to investigate the feasibility and produce prototype of a rapid-cooling device using Peltier technology. As project is based on peltier effect our first main step is selection of right peltier module. For selection of module following factors should be consider,

1. Its operating temperature must be within required limits.
2. Heat rejected by hot side of module should be less than its total power capacity.
3. For desired cooling proper heat sink should be provided on hotter side.
4. Peltier module should be selected according to the volume which has to be cooled.



CAD MODEL OF SOLAR REFRIGERATOR USING PELTIER EFFECT

5. Mathematical Definition

5.1 Theoretical efficiency-

Expected formula for coefficient of performance is-

COP = Q/W

where,

$Q = \alpha I T_c - 0.5 I^2 R - K(T_h - T_c)$

$W = \alpha I(T_h - T_c) + I^2 R$

α - seebeck coefficient = V/T_h

R - resistance

I - current

K – thermal conductivity = $[(T_h - \Delta T_{max}) * V * I] / [2(\Delta T_{max} * T_h]$

T_h – temperature of hot surface

T_c – temperature of cold

5.2 Actual efficiency-

COP = Q/P

Where Q = Refrigeration effect

$Q = (m * C_p * \Delta T)/(t * 60)$

Where $\Delta T = T_{initial} - T_{final}$

6. Objectives

The overall short term aim was to develop a small, inexpensive and compact coolerbox using a TEC heat exchanger. As has already been explained in section above an important design parameter should be the ability to function under variable input power conditions. By using a coolerbox, all the power provided by the PV system could be utilized during the day, achieving very high overall efficiency for the PV system.

1. To make use of environmentally friendly refrigeration system.
2. To investigate the cost and effectiveness of the design or TE module.
3. To identify the improvements on the experiment.
4. To study the results coming out from this project.
5. To compare results with theoretical result.
6. To look at commercially available 12VDC coolerboxes.
7. To construct a test on the behavior and specifications of a TEC heatexchanger operating in a cooler box environment.

7. Advantages of the machine

1. Light weight and compact for very small heat loads.
2. No moving parts, eliminating vibration, noise, and problems of wear.
3. Reversing the direction of current transforms the cooling unit into a heater.
4. Operates in any orientation. Not affected by gravity or vibration
5. Very low cost device for cooling in small appliances.
6. Precision temperature control capability

8. Disadvantages of the machine

1. Limited to very small refrigeration volume.
2. Compared to conventional refrigerators cooling achieved is less.
3. Heat sinks required to conduct heat to and from the thermoelectric modules become very heavy and bulky as the refrigeration capacity increases.

9. Applications of the machine

1. Medical field- Pharmaceutical industry, medicine and medical equipment storage, etc.
2. Military- storing of consumable goods in war affected zones, rural area, etc.
3. Dairy (milk) industry.
4. Mechanical industry.
5. Scientific and Laboratory Equipment— cooling chambers; freezers; cooling incubators; temperature stabilized chambers; cold laboratory plates and tables; thermo-calibrators; stage coolers; thermostats; coolers and temperature stabilisers for multipurpose sensors
6. Restaurant and hotel.
7. Vegetable, fish, fruit, beverage, etc. storage.
8. Electronic— miniature cooling units for incoming stages of highly sensitive receivers and amplifiers; coolers for high power generators, laser emitters and systems, CCD cameras, parametic-amplfiers, vacuum and solid-state photo detectors and CPU coolers.

10. Conclusion

The TE devices can act as coolers, heat pumps, power generators, or thermal energy sensors and are used in almost all the fields such as military, aerospace, instrument, biology, medicine, industrial or commercial products. The major challenge faced in TE cooling is lower COP especially in large capacity systems. However, as the energy costs are elevating and environmental regulations regarding the manufacture and release of CFCs have become more firm with time, the scope of TE effect has revived, especially in the developing countries or the third world where the energy is not surplus. TE chilling of beverage can be done at the farm level to inhibit any enzymatic or microbial change in quality of the beverage. Research in `the field of thermoelectricity and experimentation with different materials is required to improve the COP of the TE cooler. In the coming years thermoelectricity has a lot of potential to create energy saving and effective solutions for the industry and commercially as well.The minimum temperature achieved was found to be 15◦c for cooling and the maximum temperature was 65◦c for heating in this experiment.

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